Amendments to the Claims

This listing of the Claims will replace all prior versions and listings of the claims in this patent application.

Listing of the Claims

1. (canceled)

2. (currently amended) ~~The method according to Claim 1~~ A method to form a VLSI-photonic heterogeneous system device, said method comprising:

providing an optical substrate comprising at least one passive optical component formed therein wherein said optical substrate is a wafer comprising a plurality of die, wherein each said die comprises at least one said passive optical component~~,~~;

providing an electronic substrate comprising at least one active electronic component formed therein wherein said electronic substrate is a wafer comprising a plurality of die, and wherein each said die comprises at least one said active electronic component;

forming a plurality of metal pillars through said optical substrate and protruding out a first surface of said optical substrate;

forming a plurality of metal pads on a first surface of said electronic substrate; and

bonding together said optical substrate and said electronic substrate by a method further comprising:

aligning said first surfaces of said optical and electronic substrates such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and electronic substrates such that said metal pillars bond to said metal pads.

3. (original) The method according to Claim 2 wherein said optical wafer and said electronic wafer each contain alignment marks so that said wafers can be accurately aligned one to another.

4. (currently amended) The method according to Claim ~~1~~ 2 wherein said electronic substrate comprises a photodetector device, wherein said optical substrate transmits an optical signal, and wherein a vertical waveguide transmits said optical signal through said electronic substrate to said photodetector device.

5. (currently amended) The method according to Claim ~~1~~ 2 wherein said passive optical component is a waveguide, a splitter, a multiplexer, a demultiplexer, an add/drop filter, a ring resonator, ~~or~~ a waveguide optical switch, or a combination thereof.

6. (currently amended) The method according to Claim ~~1~~ 2 wherein said passive optical component is a thin film, a Si-based waveguide, a silica waveguide, a photonic crystal, or combinations thereof.

7. (currently amended) The method according to Claim ~~1~~ 2 wherein said active electronic component is a Si modulator, a trans-impedance amplifier, a clock recovery circuit, a laser driver circuit, a multiplexing circuit, a demultiplexing circuit, a radio frequency processing circuit, a baseband processing circuit, or a combination thereof.

8. (currently amended) The method according to Claim ~~1~~ 2 wherein said step of thermally treating is performed at a temperature of between about 100 °C and about 500 °C.

9. (original) The method according to Claim 8 wherein said step of bonding together further comprises a pre-plasma surface treatment of said protruding metal pillars and said metal pads prior to said step of thermally treating.

10. (original) The method according to Claim 1 wherein said passive optical component comprises a waveguide and wherein said waveguide further comprises an embedded mirror.

11. (original) The method according to Claim 10 wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that an optical signal path is formed through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

12. (original) The method according to Claim 11 wherein said vertical waveguide and said optical substrate waveguide comprise the same material.

13-23. (canceled)

24. (currently amended) The method according to Claim ~~1~~ 2 further comprising:

etching said optical substrate after said step of bonding together such that said metal pillars protrude out of said optical substrate at a second surface opposite said electronic substrate;

providing a third substrate with metal pads on a first surface; and

bonding together said optical substrate and said third substrate by a method further comprising:

aligning said second surface of said optical substrate and said first surface of said third substrate such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and third substrates such that said metal pillars bond to said metal pads.

25. (original) The method according to Claim 24 wherein said third substrate comprises either an electronic substrate comprising at least one active electronic component formed therein or an optical substrate comprising at least one passive optical component formed therein.

26-30. (canceled)

31-33. (canceled)

34. (currently amended) ~~The device according to Claim 31~~ A VLSI- photonic heterogeneous system device, said device comprising:

an optical substrate comprising:

at least one passive optical component formed therein; and

a plurality of metal pillars through said optical substrate and protruding out a first surface of said optical substrate; and

an electronic substrate comprising:

at least one active electronic component formed therein; and

a plurality of metal pads on a first surface of said electronic substrate wherein said first surfaces of said optical substrate and said electronic substrate are held together by the bonding between said metal pillars and said metal pads, and wherein said electronic substrate comprises a photodetector device, wherein said optical substrate transmits an optical signal, and wherein a vertical waveguide transmits said optical signal through said electronic substrate to said photodetector device.

35. (currently amended) The device according to Claim ~~31~~ 34 wherein said passive optical component comprises a waveguide, a splitter, a multiplexer, a demultiplexer, an add/drop filter, a ring resonator, or a waveguide optical switch.

36. (currently amended) The device according to Claim ~~31~~ 34 wherein said active electronic component comprises a Si modulator, a trans-impedance amplifier, a clock recovery circuit, a

laser driver circuit, a multiplexing circuit, a demultiplexing circuit, a radio frequency processing circuit, or a baseband processing circuit.

37. (currently amended) The device according to Claim ~~31~~ 34 wherein said passive optical component comprises a waveguide and wherein said waveguide further comprises an embedded mirror.

38. (original) The device according to Claim 37 wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that an optical signal path is formed through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

39. (original) The device according to Claim 38 wherein said vertical waveguide and said optical substrate waveguide comprise the same material.

40-48. (canceled)

49. (currently amended) The device according to Claim ~~31~~ 34 further comprising a third substrate comprising a plurality of metal pads on a first surface of said third substrate wherein a second surface of said optical substrate, opposite from said electronic substrate, and said first surface of said third substrate are held together by the bonding between said metal pillars and said third substrate metal pads.

50. (currently amended) The method according to Claim 49 wherein said third substrate comprises either an electronic substrate comprising at least one active electronic component formed therein or an optical substrate comprising at least one passive optical component formed therein.

51-53. (canceled)

54. (new) The device according to Claim 34 wherein said optical substrate is a wafer comprising a plurality of die, wherein each said die comprises at least one said passive optical component, wherein said electronic substrate is a wafer comprising a plurality of die, and wherein each said die comprises at least one said active electronic component.

55. (new) The device according to Claim 54 wherein said optical wafer and said electronic wafer each contain alignment marks so that said wafers can be accurately aligned one to another.

56. (new) A method to form a VLSI-photonic heterogeneous system device, said method comprising:

providing an optical substrate comprising at least one passive optical component formed therein;

providing an electronic substrate comprising at least one active electronic component formed therein;

forming a plurality of metal pillars through said optical substrate and protruding out a first surface of said optical substrate;

forming a plurality of metal pads on a first surface of said electronic substrate;

bonding together said optical substrate and said electronic substrate by a method further comprising:

aligning said first surfaces of said optical and electronic substrates such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and electronic substrates such that said metal pillars bond to said metal pads;

thereafter etching said optical substrate such that said metal pillars protrude out of said optical substrate at a second surface opposite said electronic substrate;

providing a third substrate with metal pads on a first surface; and

bonding together said optical substrate and said third substrate by a method further comprising:

aligning said second surface of said optical substrate and said first surface of said third substrate such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and third substrates such that said metal pillars bond to said metal pads.

57. (new) The method according to Claim 56 wherein said optical substrate is a wafer comprising a plurality of die, wherein each said die comprises at least one said passive optical component, wherein said electronic substrate is a wafer comprising a plurality of die, and wherein each said die comprises at least one said active electronic component.

58. (new) The method according to Claim 57 wherein said optical wafer and said electronic wafer each contain alignment marks so that said wafers can be accurately aligned one to another.

59. (new) The method according to Claim 56 wherein said electronic substrate comprises a photodetector device, wherein said optical substrate transmits an optical signal, and wherein a vertical waveguide transmits said optical signal through said electronic substrate to said photodetector device.

60. (new) The method according to Claim 56 wherein said passive optical component is a waveguide, a splitter, a multiplexer, a demultiplexer, an add/drop filter, a ring resonator, ~~or~~ a waveguide optical switch, or a combination thereof.

61. (new) The method according to Claim 56 wherein said passive optical component is a thin film, a Si-based waveguide, a silica waveguide, a photonic crystal, or combinations thereof.

62. (new) The method according to Claim 56 wherein said active electronic component is a Si modulator, a trans-impedance amplifier, a clock recovery circuit, a laser driver circuit, a multiplexing circuit, a demultiplexing circuit, a radio frequency processing circuit, a baseband processing circuit, or a combination thereof.

63. (new) The method according to Claim 56 wherein said step of thermally treating is performed at a temperature of between about 100 °C and about 500 °C.

64. (new) The method according to Claim 63 wherein said step of bonding together further comprises a pre-plasma surface treatment of said protruding metal pillars and said metal pads prior to said step of thermally treating.

65. (new) The method according to Claim 56 wherein said passive optical component comprises a waveguide and wherein said waveguide further comprises an embedded mirror.

66. (new) The method according to Claim 65 wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that an optical signal path is formed through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

67. (new) The method according to Claim 66 wherein said vertical waveguide and said optical substrate waveguide comprise the same material.

68. (new) The method according to Claim 56 wherein said third substrate comprises either an electronic substrate comprising at least one active electronic component formed therein or an optical substrate comprising at least one passive optical component formed therein.

69. (new) A method to form a VLSI-photonic heterogeneous system device, said method comprising:

providing an optical substrate comprising at least one passive optical component formed therein wherein said passive optical component comprises a waveguide and wherein said waveguide further comprises an embedded mirror;

providing an electronic substrate comprising at least one active electronic component formed therein;

forming a plurality of metal pillars through said optical substrate and protruding out a first surface of said optical substrate;

forming a plurality of metal pads on a first surface of said electronic substrate;

bonding together said optical substrate and said electronic substrate by a method further comprising:

aligning said first surfaces of said optical and electronic substrates such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and electronic substrates such that said metal pillars bond to said metal pads.

70. (new) The method according to Claim 69 wherein said optical substrate is a wafer comprising a plurality of die, wherein each said die comprises at least one said passive optical component, wherein said electronic substrate is a wafer comprising a plurality of die, and wherein each said die comprises at least one said active electronic component.

71. (new) The method according to Claim 70 wherein said optical wafer and said electronic wafer each contain alignment marks so that said wafers can be accurately aligned one to another.

72. (new) The method according to Claim 69 wherein said electronic substrate comprises a photodetector device, wherein said optical substrate transmits an optical signal, and wherein a vertical waveguide transmits said optical signal through said electronic substrate to said photodetector device.

73. (new) The method according to Claim 69 wherein said passive optical component is a waveguide, a splitter, a multiplexer, a demultiplexer, an add/drop filter, a ring resonator, ~~or~~ a waveguide optical switch, or a combination thereof.

74. (new) The method according to Claim 69 wherein said passive optical component is a thin film, a Si-based waveguide, a silica waveguide, a photonic crystal, or combinations thereof.

75. (new) The method according to Claim 69 wherein said active electronic component is a Si modulator, a trans-impedance amplifier, a clock recovery circuit, a laser driver circuit, a multiplexing circuit, a demultiplexing circuit, a radio frequency processing circuit, a baseband processing circuit, or a combination thereof.

76. (new) The method according to Claim 69 wherein said step of thermally treating is performed at a temperature of between about 100 °C and about 500 °C.

77. (new) The method according to Claim 76 wherein said step of bonding together further comprises a pre-plasma surface treatment of said protruding metal pillars and said metal pads prior to said step of thermally treating.

78. (new) The method according to Claim 69 wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that an optical signal path is formed through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

79. (new) The method according to Claim 78 wherein said vertical waveguide and said optical substrate waveguide comprise the same material.

80. (new) The method according to Claim 69, after said bonding together said optical substrate and said electronic substrate, further comprising:

etching said optical substrate such that said metal pillars protrude out of said optical substrate at a second surface opposite said electronic substrate;

providing a third substrate with metal pads on a first surface; and

bonding together said optical substrate and said third substrate by a method further comprising:

aligning said second surface of said optical substrate and said first surface of said third substrate such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and third substrates such that said metal pillars bond to said metal pads.

81. (new) The method according to Claim 80 wherein said third substrate comprises either an electronic substrate comprising at least one active electronic component formed therein or an optical substrate comprising at least one passive optical component formed therein.